DOCUMENT RESUME

ED 197 957 SE 034 020

AUTHOR Sachar, Jane: Baker, Meryl S.
TITLE Mathematical Requirements in Navy Class "A" Electronics Schools.
INSTITUTION Navy Personnel Research and Development Center, San Diego, Calif.
REPORT NO NPRDC-TR-81-4
PUB DATE Jan 81
NOTE 49p.: Appendix marginally legible.

EDRS PRICE MF01/PC02 Plus Postage.
DESCRIPTORS *Basic Skills: *Educational Research: *Electronic Technicians: Engineering: Engineering Education: Mathematical Concepts: *Mathematics Education: Mathematics Instruction: *Postsecondary Education: School Surveys

ABSTRACT

Instructors in 14 Navy electronics "A" schools (12 basic core and 2 advanced) were presented with a list of 70 mathematical skills and asked to indicate: (1) how important they were to successful school performance, and (2) whether they were prerequisite, reviewed, or taught in the "A" schools. They were also asked to state the number and type of performance aids used in the course and during the exam. Responses showed that of the 70 skills surveyed, 19 do not appear in any basic core course and 2 more do not affect performance. Although the skills rated as affecting performance are generally considered as prerequisite in all schools, many students require review in these skills for successful performance. Across all schools, the most important skills are: (1) addition, subtraction, multiplication, and division of numbers: (2) squares and square roots of positive numbers: (3) addition and subtraction of like units: (4) multiplication and division of like and/or unlike units: (5) substitution of known values into a given formula: and (6) transpositions of algebraic expressions. Performance aids are permitted in all courses but one, both during the course and during exams. (Author/MP)

****
* Reproductions supplied by EDRS are the best that can be made *
* from the original document. *
****

SE 034 020

ED197957

U S DEPARTMENT OF HEALTH,
EDUCATION & WELFARE
NATIONAL INSTITUTE OF
EDUCATION

THIS DOCUMENT HAS BEEN REPRODUCED EXACTLY AS RECEIVED FROM THE PERSON OR ORGANIZATION ORIGINATING IT. POINTS OF VIEW OR OPINIONS STATED DO NOT NECESSARILY REPRESENT OFFICIAL NATIONAL INSTITUTE OF EDUCATION POSITION OR POLICY

NPRDC TR 81-4

January 1981

MATHEMATICAL REQUIREMENTS IN NAVY CLASS "A" ELECTRONICS SCHOOLS

Jane Sachar
Meryl S. Baker

Reviewed by
Edwin G. Aiken

Released by
James F. Kelly, Jr.
Commanding Officer

Navy Personnel Research and Development Center
San Diego, California 92152

JAN 2 6 1981

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER: NPRDC TR 81-4	2. GOVT ACCESSION NO.
3. RECIPIENT'S CATALOG NUMBER	
4. TITLE (and Subtitle): MATHEMATICAL REQUIREMENTS IN NAVY CLASS "A" ELECTRONICS SCHOOLS	5. TYPE OF REPORT & PERIOD COVERED: 1 Feb 78 - 1 Nov 78
	6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s): Jane Sachar, Meryl S. Baker	8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS: Navy Personnel Research and Development Center, San Diego, California 92152	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS: 62757N, ZF55-522-011-03.02
11. CONTROLLING OFFICE NAME AND ADDRESS: Navy Personnel Research and Development Center, San Diego, California 92152	12. REPORT DATE: December 1980
	13. NUMBER OF PAGES: 21
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)	15. SECURITY CLASS. (of this report): UNCLASSIFIED
	15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Mathematics
Prerequisite skills
Performance aids
Electronic "A" Schools

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Instructors in 14 Navy electronics "A" schools (12 basic core and 2 advanced) were presented with a list of 70 mathematical skills and asked to indicate (1) how important they were to successful school performance and (2) whether they were prerequisite, reviewed, or taught in the "A" schools. Also, they were asked to state the number and type of performance aids used in the course and during the exam. Responses showed that, of the 70 skills surveyed, 19 do not appear in any basic core course and 2 more do not affect performance. Although the skills rated as affecting performance are generally

considered as prerequisite in all schools, many students require review in these skills for successful performance. Across all schools, the most important skills are (1) addition, subtraction, multiplication, and division of numbers, (2) squares and square roots of positive numbers, (3) addition and subtraction of like units, (4) multiplication and division of like and/or unlike units, (5) substitution of known values into a given formula, and (6) transpositions of algebraic expressions. Performance aids are permitted in all courses but one, both during the course and during exams.

FOREWORD

This research and development was conducted under Exploratory Development Task Area ZF-63-522-011 (The Assessment and Enhancement of Prerequisite Skills), Work Unit 522-011-03.02 (Enhancement of Computational Capabilities), and was sponsored by the Chief of Naval Education and Training. The objectives of the work unit are to identify mathematical skill deficiencies among Navy electronics personnel, to determine the causes of such deficiencies, and to develop instructional strategies to improve the efficiency and job relevance of Navy electronics training. The objective of the effort described herein is to identify the mathematical skills required to perform successfully in Navy electronics "A" schools. Subsequent reports will assess personnel performance at these schools, compare performance with requirements for success, and offer recommendations for curriculum revision. Results are intended for use by the Chief of Naval Education and Training and the Chief of Naval Technical Training.

Appreciation is expressed to the Navy "A" school instructors who participated in this study.

JAMES F. KELLY, JR.
Commanding Officer

JAMES J. REGAN
Technical Director

SUMMARY

Problem

The sophistication of military equipment is increasing while training budgets are decreasing. Thus, to assure cost-effective training, those skills and knowledges that are essential for successful job performance in the fleet must be identified, as well as the subordinate skills and knowledges that enable the trainee to master essential skills.

Objective

The objective of this effort was to identify mathematical skills required for successful performance in the Navy electronics "A" schools. It is the first in a series of reports designed to identify mathemathical requirements relevant to electronics training.

Approach

Instructors in 14 electronics "A" schools (12 basic and 2 advanced) were asked to assess the importance of 70 mathematical skills for successful electronics course performance, to indicate whether the surveyed skills are prerequisite, reviewed, or taught by the "A" schools, and to state the number and type of performance aids used in each school. Also, in a follow-up survey, instructors from four schools were asked how much time was spent in each school reviewing and teaching all mathematics topics surveyed.

Findings

1. The number of math skills rated as affecting performance in a basic core course ranged from 14 (Construction Electrician (CE) School) to 41 (Sonar Technician (ST) School). The two advanced courses included in the study, the Advanced First Term Avionics (AFTA) and the Fire Control Technician II (FTII) courses, require 59 and 28 skills, respectively.

2. All of the skills rated as affecting performance are considered as prerequisites in all schools, except for transposition of algebraic expressions, which is taught in the Gunner's Mate (GM) School. All of these skills, however, are reviewed by one or more schools.

3. Across all schools, the most important skills are (a) addition, subtraction, multiplication, and division of numbers, (b) squares and square roots of positive numbers, (c) addition and subtraction of like units, (d) multiplication and division of like units, (e) multiplication and division of unlike units, (f) substitution of known values into a given formula, and (g) transpositions of algebraic expressions.

4. Of the 70 skills in the survey, 19 do not appear in any basic core courses, and 2 more do not affect performance. These skills are in the Logarithms (1), Equations (2), Algebraic Expressions (7), Determinants (2), Geometry and Trigonometry (5), and Phasors (4) topic areas.

5. Four standard electronics units--volt, ohm, amp, and watt--are used in all courses. Only 4 of the 14 courses use the meter.

6. Performance aids are permitted in all courses except the Data System Technician (DS) course, both during the course and during exams. The nonprogrammable calculator is the most universally used performance aid for math computation.

7. Instructors at the four schools participating in the follow-up survey reported that between one and five percent of total training time was spent in reviewing or teaching mathematics.

Conclusions

1. Although a number of mathematical skills are considered to be course prerequisites, many students require instruction in these skills in the form of review or reteaching.

2. In most courses, students are not required to perform mathematics operations manually.

3. The amount of time spent on review and teaching of mathematics is minimal.

Recommendations

1. Further studies should be conducted to:

a. Determine if "A" school mathematics requirements are justified; that is, if they are necessary for fleet performance or as an enabling skill for another skill critical to fleet performance.

b. Determine if entry levels of electronics Class "A" school students match prerequisite requirements.

c. Determine the extent to which Basic Electricity and Electronics Preparatory Schools provide training in mathematical skills considered as prerequisite to the electronics Class "A" schools.

2. Given the variability of mathematical skills required in the Navy's electricity/electronics courses, curriculum developers should ensure that curricula are designed to provide instruction only in those skills required by an individual course.

CONTENTS

	Page
INTRODUCTION	1
Problem	1
Background	1
Purpose	2
METHOD	2
Study Participants	2
Survey Development	4
Administration	4
Follow-up Survey	4
RESULTS AND DISCUSSION	7
Original Survey	7
Importance and Skill Acquisition Level Ratings	7
Units	12
Number Bases	12
Performance Aids	12
Follow-up Survey	15
CONCLUSIONS	16
RECOMMENDATIONS	16
REFERENCES	17
APPENDIX A: MATHEMATICAL SKILLS SURVEY	A-0

LIST OF TABLES

1.	Class "A" Courses Included in Study	3
2.	Importance (I) and Skill Acquisition Level (L) Ratings Assigned to Mathematical Skills	8
3.	Units Used Most Frequently in Electronics Courses	13
4.	Performance Aids Permitted in Electronics Courses	14
5.	Mean Time Spent Reviewing (R) and Teaching (T) Math Topics Surveyed	15

INTRODUCTION

Problem

The sophistication of military equipment is increasing while training budgets are decreasing. Thus, to assure cost-effective training, those skills and knowledges that are essential for successful job performance in the fleet must be identified, as well as the subordinate skills and knowledges that enable the trainee to master essential skills.

Navy recruits are assigned to ratings and corresponding Class "A" schools based on scores obtained on the Armed Services Vocational Aptitude Battery (ASVAB), which measures aptitudes in a number of areas. Over 23,000 of the approximately 60,000 recruits who enter Navy Class "A" schools every year are trained in electronics maintenance. Before these recruits enter "A" school, however, they must successfully undergo initial training on the fundamentals of electronic theory at one of the Basic Electricity and Elelctronics (BE/E) preparatory schools, which are located at Orlando, FL; Memphis, TN; Great Lakes, IL; and San Diego, CA. The course at the BE/E schools consists of a series of modules, each comprised of one or two units. Students scheduled to enter the electronics ratings must master the first 11 modules of the BE/E course before proceeding to more specialized training. Since the BE/E course and all follow-on courses use mathematics to express relationships in electronic systems, a diagnostic mathematics test is given prior to BE/E. Students who have deficiencies in mathematics are referred to remedial mathematics units, but are not tested on these units.

Although the background required for the electronics "A" school is more stringent than in most areas of Navy technical training and the preliminary instruction most advanced, "A" school instructors frequently report that many students are not prepared to begin "A" school curricula. They cite mathematical skills as a primary deficiency among students and view this inadequacy as significantly contributing to unsatisfactory performance in electronics. Since electronics theory is, to some degree, mathematical, and since course curricula generally rely on the mathematical foundations of theory, it follows that deficiencies in math would interfere with the learning of electronics.

Background

Steinemann (1965), in an attempt to obtain detailed information regarding electronics training in military and civilian organizations, surveyed mathematical skills in Navy Electronics Technician (ET), Fire Control Technician (FT), Sonar Technician (ST), and Avionics Technician (AV) Class "A" schools, and in Radioman "B" schools. He found that "some algebra, trigonometry, powers-of-ten, roots and squares, logarithms, and binary arithmetic are commonly included" in most Class "A" electronics courses. However, he noted that uniform acceptance of particular mathematical skills in the curriculum "is not necessarily proof that they are needed by the average technician in the performance of his duties."

Stauffer (1955) developed tests of mathematics skill and knowledge of electricity for use in determining training requirements for sonar maintenance. He found that results of mathematics and electricity subtests predicted, to a statistically significant degree, student success in the sonar maintenance training program. However, his report did not include a detailed account of the analysis procedures employed, a list of the skills that were tested, or the items that comprised the tests.

Cox and Montgomery (1964), in an investigation of mathematics skill requirements for Army basic electronics courses, identified 19 specific computational skills and constructed a test to measure them. Although test results showed that most of the mathematical skills were moderately related to success in basic electronics, no single skill was a "powerful predictor of any available estimate of success."

Johnson (1969), as part of a broader study, interviewed instructors and found that computational skills then being taught in avionics fundamental courses were generally viewed as "enabling skills"; that is, skills taught to facilitate the learning of other, more job-oriented skills. Also, he presented the instructors with several dozen items on computational skills, and asked them to indicate the relevance of each skill to job performance. Although the instructors rated only two of the computational skills as relevant to the job, most of them felt that such skills were an aid to further training.

Anderson (1962) constructed a mathematical achievement test to measure ETs' basic abilities in powers-of-ten, square roots, algebra, logarithms, trigonometry, and binary arithmetic. Results of the test indicated that, in general, ETs not only lacked proficiency in mathematics but, also, that there was no "appreciable relationship between their test results and job proficiency." As a result, Anderson questioned whether the content of the ET course was appropriate.

While mathematical skill does not relate to job performance, it has been a good predictor of electronics training success. However, since this finding is based on correlations that, by themselves, do not adequately define the relationship between mathematics ability and electronics peformance, it is necessary to determine more conclusively whether mathematics is an enabling skill for learning electronics.

Enabling or subordinate skills are derived through a task analysis procedure in which each "terminal" or higher-order task or skill is systematically analyzed to determine the enablers that comprise it. Hence, if mathematics is an enabler for learning electronics, a better insight into the relationship between electronics performance and mathematical ability, beyond that offered by correlational data, should be obtained.

Purpose

The purpose of this study was to determine those mathematical skills identified by course instructors as required for successful performance in Navy electronics Class "A" schools. The validity of those requirements was not addressed.

METHOD

Study Participants

The 14 "A" school courses listed in Table 1 were included in the study. Twelve of these courses--all but the Advanced First Term Avionics (AFTA) and the Fire Control Technician II (FTii) courses--are attended by BE/E school graduates and focus on the respective "A" school core skills and knowledges. All of these schools graduate at least 100 students per year.[1] AFTA and FTII are advanced courses attended only by students who rank academically in the upper two-thirds of their respective basic core courses.

---

[1]Although the Interior Communications Electrician School (IC) graduates more than 100 students annually, it was not included in this study because it was undergoing major curriculum changes at the time of data collection.

Table 1

Class "A" Courses Included in Study

Class "A" Courses	Location	Number of Instructors Responding to Survey
Aviation Electrician's Mate (AE)	Memphis	7
Avionic Technician (AVA)	Memphis	9
Advanced First Term Avionics (AFTA)[a]	Memphis	8
Construction Electrician (CE)[b]	Gulfport	3
Construction Electrician (CE)[b]	Port Hueneme	5
Data Systems Technician (DS)	Mare Island	9
Electricians Mate (EM)	Great Lakes	5
Electronics Technician (ET)	Great Lakes	4
Electronics Warfare Technician (EW):[c]		
EW Corrective Maintenance (EWC)	Pensacola	3
EW Preventive Maintenance (EWP)	Pensacola	3
Fire Control Technician I (FTI)	Great Lakes	3
Fire Control Technician II (FTII)[a]	Great Lakes	3
Gunner's Mate (GM)	Great Lakes	5
Sonar Technician (ST)	San Diego	3
Total		70

[a]These are advanced courses attended only by students who rank academically in the upper two thirds of their respective basic core courses.

[b]Two locations of the CE school were surveyed and treated independently to determine whether instructor responses were consistent across locales.

[c]Data were obtained separately for the preventive and corrective maintenance sections of the EW school since each section represented a distinct block of instruction taught by different instructors.

Survey Development

Several electronics math textbooks, including the principal one used by Navy electronics schools, Basic Mathematics for Electronics (Cooke and Adams, 1970), were reviewed to develop a list of candidate math skills. Seventy skills were identified, and grouped into the 14 topic areas shown in Figure 1.

A survey form was then developed, which included two example problems for each of the 70 skills identified. These problems represented the range of difficulties found in the review of electronics math materials. For each skill, respondents were asked to indicate the level of importance of the skill to the course. Responses were to be made on a 6-point scale, where 5 = Indispensable, and 0 = Not required. For skills rated as affecting performance (i.e., rated above 1), respondents were asked to indicate the level of instruction provided. Responses were made on a 3-point scale, where P = Prerequisite (must possess skill on entrance to course), R = Reviewed (some level of skill is assumed, but skill is reviewed in course), and T = Taught (no previous knowledge assumed; taught explicitly as a skill for the course).

A copy of the skills survey is provided in the appendix.

Administration

The survey was administered simultaneously to senior instructors at the 14 schools listed in Table 1, during the period from 27 June through 21 July 1978. After providing instructors with a copy of the survey, the experimenter explained the purpose of the research project and the survey, gave general instructions, and read aloud the definitions for each rating of importance and level of instruction. It was stressed that responses should apply to the entire course as presently taught, and not to the instructor's opinion of how the course should be taught.

After the instructors completed their survey, which took from 10 to 20 minutes, the experimenter discussed the entire survey with the group, one skill at a time. Skills that elicited different responses were discussed and a consensus, if reached, was recorded by the experimenter. If consensus could not be reached, the individual responses were recorded by the experimenter. Major response changes occurred when an instructor forgot how a particular skill was used, or when he rated the skill as important but later realized it was used little or not at all in his course. The entire session was tape recorded and required approximately 1.5 hours.

After the discussion session, the instructors were asked to list the kind of math performance aids (e.g., calculators, formula sheets, slide rules), if any, students use during the course and/or during the exam. Also, they were asked to indicate the units of measurement and the number bases (binary, octal, or hexidecimal) that are used in the course.

Follow-up Survey

A follow-up survey was administered to senior instructors at the ET, GM, EM, and FTI Class "A" schools at Great Lakes, IL. (In some cases, instructors participating in the follow-up survey were the same as those who participated in the original survey.) This survey was identical to the first, except that respondents were also asked to indicate how much instructional time was spent in reviewing and teaching skills that instructors in the original survey had designated as being reviewed or taught.

Arithmetic Operations with Numbers (4):

1. Addition, subtraction, multiplication, and division of numbers
2. Squares and square roots of positive numbers
3. Powers and roots of positive numbers greater than squares and square roots
4. Percentages of numbers

Estimation (1):

5. Estimation of answers to arithmetic computation

Fractions (5):

6. Addition and subtraction of fractions
7. Multiplication and division of fractions
8. Powers and roots of fractions
9. Reduction of numeral fractions to lowest terms
10. Simplification of complex fractions

Units and Conversions (7):

11. Addition and subtraction of like units
12. Multiplication and division of like units
13. Multiplication and division of unlike units
14. Squares and square roots of units
15. Unit conversion between nonmetric and metric systems
16. Unit conversion within a metric system
17. Unit conversion within a nonmetric system

Scientific Notations (4):

18. Representation of numbers in scientific notation
19. Addition and subtraction of numbers in scientific notation
20. Multiplication and division of numbers in scientific notation
21. Powers and roots of numbers in scientific notation

Decibels (1):

22. Decibels

Logarithms (4)

23. Logs and antilogs found from log tables
24. Arithmetic computation using logs
25. Solution of logarithmic and exponential equations
26. Logs of numbers to bases other than 10, using base 10 log tables

Equations (6):

27. Substitution of known values into a given formula
28. Transpositions of algebraic expressions
29. Application of transpositions on equations with more than one variable
30. Solutions of quadratic equations
31. Solutions of second-order simultaneous equations
32. Solutions of third-order simultaneous equations

Figure 1. Skills identified as being related to performance at Navy electronics Class "A" Schools.

Algebraic Expressions (9):

33. Addition and subtraction of algebraic expressions
34. Multiplication and division of simple algebraic expressions
35. Multiplication of algebraic expressions up to binomials
36. Multiplication of algebraic expressions larger than binomials
37. Division of algebraic expressions
38. Powers and roots of simple algebraic expressions
39. Powers and roots of polynomials
40. Addition and subtraction of fractional algebraic expressions
41. Factoring algebraic expressions

Determinants (2):

42. Evaluation of determinants
43. Solutions of simultaneous equations using determinants

Geometry and Trigonometry (8):

44. Conversion of radian and degree measures of angles
45. Pythagorean theorem
46. Use of trigonometric tables to find specified function of a given angle or the angle of a given function
47. Solutions to right triangles
48. Calculations of the area of a given triangle
49. Solutions for unknown parts of a nonright triangle using laws of sines or cosines
50. Solutions of amplitude, frequency, phase angle, period, and angular velocity of a given periodic function
51. Amplification of sum and difference identities

Phasors (7):

52. Conversion of polar and rectangular coordinates
53. Powers and roots of signed numbers
54. Addition and subtraction of phasors in rectangular form
55. Addition and subtraction of polar phasors
56. Multiplication and division of phasors in rectangular form
57. Multiplication and division of polar phasors
58. Powers and roots of polar phasors

Number Bases (4):

59. Conversion of numbers to different number systems
60. Addition and subtraction in number systems from #59
61. Multiplication and division in number systems from #59
62. Complements of binary numbers

Boolean Algebra (8):

63. Conversion of Boolean expressions to truth tables
64. Conversion of logic diagrams to truth tables
65. Conversions of Boolean expressions to logic diagrams
66. Simplification of Boolean expressions
67. Conversion of logic diagrams to Boolean expressions
68. Simplification of Boolean expressions involving minterms (Veitch diagrams)
69. Conversion of truth tables to Boolean expressions
70. Conversion of truth tables to logic diagrams

Figure 1. (Continued)

RESULTS AND DISCUSSION

Original Survey

Importance and Skill Acquisition Level Ratings

Table 2 presents the importance and skill acquisition ratings assigned to the 70 mathematical skills surveyed by instructors at the 14 schools. As shown, the number of skills required or rated as affecting performance (i.e., rated above "1" on the survey) in the basic core courses ranges from 14 in the CE-G and CE-P schools to 41 in the ST school. AFTA and FT II, the two advanced courses included in the analysis, require 59 and 28 skills respectively. If digital math (Number Bases and Boolean Algebra), which is not included in traditional high school curricula, is excluded, the number of skills required in basic core courses ranges from 11 in DS to 29 in ST. AFTA and FTII would require 48 and 18 skills respectively.

Sets of math skills are not common across courses. In fact, only five skills--numbers 1 and 2 (Arithmetic Operations with Numbers) and 11-13 (Units and Conversions) appear in every common core course. These skills, along with skills 27 and 28 (Equations) tend to receive high ratings across all basic courses. Since these skills are the building blocks for all quantitative electronics problems, they are probably used more frequently than are the other skills.

Of the 70 skills in the survey, 19 do not appear in any basic core course, and 2 more do not affect performance. These skills are in the Logarithms (26), Equations (30, 32), Algebraic Expressions (34, 36-41), Determinants (42, 43), Geometry and Trigonometry (44, 48-51), and Phasors (53, 56-58) topic areas. No topic area is required in its entirety in every school. In fact, of the topics with more than one skill, only Scientific Notation, Number Bases, and Boolean Algebra are required in their entirety by any basic course. Determinants skills are not required in any basic course; Algebraic Expressions skills, in only one course (ST); Phasors, in only two courses (FTI and ST); and Logarithms, in only three courses (EWC, EWP, and ST).

There appear to be six skill clusters among all courses. That is, all skills in those clusters tended to be given the same importance rating by instructors within a specific school. These clusters are in Fractions (6, 7), Units and Conversions (11, 12, 13), Scientific Notation (18, 19), Logarithms (23, 25), Equations (27, 28), and Number Bases/Boolean Algebra (59, 65, 67, 69, 70). Apparently, the tasks in a course that require one skill in the cluster require the others to the same degree.

The responses given by instructors at the four electrician schools--AE, CE-G, CE-P, and EM--were similar, with instructors at the two CE schools giving the most consistent, although not identical, responses. Ten skills were rated as affecting performance in all four courses (1, 2, 4, 6, 7, 11, 12, 13, 27, & 28); four more, in three courses (9 & 45--CE-G, CE-P, & EM; 16--AE, CE-G, & EM; 17, AE, CE-G, & CE-P); three more, in two courses (5--AE & CE-P; 29 & 46--AE & EM); and five more, in one course (10, 14, 18, 19, & 64--EM). Skill numbers 1, 2, 4, 11, 12, 13, 27, and 28 tended to be rated most important (as they were in all of the basic core courses). However, of these, only number 1 was rated as indispensable to any of the four courses. The topic areas considered as affecting performance in the electrician schools were Arithmetic Operations with Numbers (1, 2, 4), Estimations (5), Fractions (6, 7, 9, 10), Units and Conversions (11, 12, 13, 14, 16, 17), Scientific Notations (18, 19), Equations (27, 28, 29), Geometry and Trigonometry (45, 46), and Boolean Algebra (64).

Table 2

Importance (I) and Skill Acquisition Level (L) Ratings Assigned to Mathematical Skills

Topic Area	Skill	AE I	AE L	AVA I	AVA L	AFTA I	AFTA L	CE-G I	CE-G L	CE-P I	CE-P L	DS I	DS L	EM I	EM L	ET I	ET L	EWC I	EWC L	EWP I	EWP L	FTI I	FTI L	FTII I	FTII L	GM I	GM L	ST I	ST L	No. of Courses in Which Skill Affects Performance
Arithmetic Operations with numbers (4)	1	5	P	5	R	5	P	4	P	5	P	5	R	4	P	5	R	5	R	5	R	5	R	5	P	5	P	4	P	14
	2	2	P	5	R	5	R	4	P	2	R	5	--	4	R	5	R	5[a]	R	1	--	4	R	0	--	2	R	4	P	12
	3	1	--	1	--	5	R	0	--	0	--	3	R	0	--	0	--	0	--	0	--	0	--	0	--	0	--	0	--	2
	4	4	P	5	R	5	R	4	P	3	R	0	--	4	R	4	R	5	R	5	R	4	R	0	--	3	R	4	P	12
		(3)		(3)		(4)		(3)		(3)		(3)		(3)		(3)		(3)		(2)		(3)		(1)		(3)		(3)		
Estimations (1)	5	2	P	2	R	3	R	1	--	2	P	2	R	1	--	3	R	0	--	0	--	1	--	0	--	0	--	2	P	7
		(1)		(1)		(1)		(0)		(1)		(1)		(0)		(1)		(0)		(0)		(0)		(0)		(0)		(1)		
Fractions (5)	6	3	R	1	--	5	T	2	P	2	R	0	--	2	R	2	R	3[a]	R	2[a]	R	1	--	4	T	2	R	4	P	11
	7	3	P	1	--	5	T	2	P	2	R	0	--	2	R	1	--	2	R	2[a]	R	1	--	4	T	2	R	2	P	10
	8	0	--	0	--	4	T	0	--	0	--	0	--	0	--	0	--	4	R	1	-	0	--	0	--	0	--	0	--	2
	9	1	--	1	--	5	R	2	P	2	R	0	--	4	P	1	--	0	--	3	R	1	--	5	R	2	R	2	P	8
	10	0	--	3	R	4	R	0	--	0	--	0	--	2	P	0	--	3	R	3	R	1	--	0	--	0	--	1	--	5
		(2)		(1)		(5)		(3)		(3)		(0)		(4)		(1)		(4)		(4)		(0)		(3)		(3)		(3)		
Units and Conversions (7)	11	4	P	5	R	5	P	2	R	4	P	5	P	4	P	5	R	5	R	5	R	4	P	4	P	3	R	4	P	14
	12	4	P	5	R	5	R	3	P	3[a]	P	5	P	4	R	5	R	5	R	5	R	4	P	4	P	2	P	3	P	14
	13	4	P	4	R	5	R	3	P	4	P	4	P	3	R	4	R	5	R	3	R	4	P	4	P	3	R	2	P	14
	14	1	--	2	R	4	R	1	--	1	--	0	--	4	R	1	--	5	R	5	R	1	--	0	--	2	R	2	P	7
	15	0	--	1	--	0	--	0	--	1	--	0	--	0	--	2	T	0	--	0	--	0	--	0	--	0	--	1	--	1
	16	3[a]	P	5	T	5	R	3	P	1	--	4	P	4	P	5	T	5	R	5	R	4	R	4	R	0	--	3	P	12
	17	2	P	5	R	4	T	3	P	?	R	1	--	0	--	3	T	5	R	5	R	4	R	5	R	3	T	0	--	11
		(5)		(6)		(6)		(5)		(4)		(4)		(5)		(6)		(6)		(6)		(5)		(5)		(5)		(5)		
Scientific Notation (4)	18	1	--	5	R	5	R	0	--	0	--	5	R	4	R	4	T	4	R	4	R	4	R	4	R	0	--	4	P	10
	19	1	--	5	R	5	R	0	--	0	--	5	R	2	R	4	T	4	R	4	R	4	R	4	R	0	--	4	P	10
	20	0	--	5	R	5	R	0	--	0	--	2	R	0	--	4	T	4	R	4	R	2	P	4	P	0	--	4	P	9
	21	0	--	1	--	4	R	0	--	0	--	0	--	0	--	4	T	4	R	3	R	0	--	0	--	0	--	4	P	5
		(0)		(3)		(4)		(0)		(0)		(3)		(2)		(4)		(4)		(4)		(3)		(3)		(0)		(4)		

Notes:

1. Importance (I) ratings are based on responses made on a 6-point scale, where 0 = Not required, 1 = Dispensable, 2 = Somewhat useful, 3 = Generally useful, 4 = Very important, and 5 = Indispensable.

2. Skill acquisition level (L) ratings are based on responses made on a 3-point scale, where P = Prerequisite, R = Reviewed, and T = Taught.

3. Numbers in parentheses are the total number of skills within a topic area that affect performance (i.e., they were rated above "1" in importance).

[a]Instructors did not reach consensus on importance ratings of these skills. Numbers given are average ratings obtained, rounded to the nearest whole number.

Table 2 (Continued)

Topic Area	Skill	AE I	AE L	AVA I	AVA L	AFTA I	AFTA L	CE-G I	CE-G L	CE-P I	CE-P L	DS I	DS L	EM I	EM L	ET I	ET L	EWC I	EWC L	EWP I	EWP L	FTI I	FTI L	FTII I	FTII L	GM I	GM L	ST I	ST L	No. of Courses in Which Skill Affects Performance
Decibels (1)	22	1	—	1	—	3	R	0	—	0	—	0	—	0	—	3	T	4	T	4	T	0	—	0	—	0	—	4	T	5
		(0)		(0)		(1)		(0)		(0)		(0)		(0)		(1)		(1)		(1)		(0)		(0)		(0)		(1)		
Logarithms (4)	23	0	—	0	—	3	R	0	—	0	—	0	—	0	—	1	—	5	T	5	T	0	—	0	—	0	—	4	T	4
	24	0	—	0	—	2	R	0	—	0	—	0	—	0	—	1	—	0	—	0	—	0	—	0	—	0	—	3	T	2
	25	0	—	0	—	2	R	0	—	0	—	0	—	0	—	1	—	5	T	5	T	0	—	0	—	0	—	3	T	4
	26	0	—	0	—	0	—	0	—	0	—	0	—	0	—	0	—	0	—	0	—	0	—	0	—	0	—	0	—	0
		(0)		(0)		(3)		(0)		(0)		(0)		(0)		(0)		(2)		(2)		(0)		(0)		(0)		(3)		
Equations (6)	27	3	P	5	R	5	R	3	P	4	R	0	—	4	R	4	R	5	R	5	R	3[a]	R	4	P	5	P	4	P	13
	28	3	P	5	R	5	R	3	P	4	R	0	—	4	R	4	R	5	R	5	R	4	R	4	R	4	T	4	P	13
	29	3	R	1	—	5	R	0	—	1	—	0	—	4	R	4	R	4	R	4	R	0	—	1	—	4	T	3	P	8
	30	0	—	0	—	0	—	0	—	0	—	0	—	0	—	0	—	0	—	0	—	0	—	0	—	0	—	0	—	0
	31	0	—	0	—	3	R	0	—	0	—	0	—	0	—	0	—	0	—	0	—	0	—	0	—	0	—	3	T	2
	32	0	—	0	—	0	—	0	—	0	—	0	—	0	—	0	—	0	—	0	—	0	—	0	—	0	—	1	—	0
		(3)		(2)		(4)		(2)		(2)		(0)		(3)		(3)		(3)		(3)		(2)		(2)		(3)		(4)		
Algebraic Expressions (9)	33	0	—	0	—	5	R	0	—	0	—	0	—	0	—	0	—	0	—	0	—	0	—	0	—	0	—	3	P	2
	34	0	—	0	—	4	R	0	—	0	—	0	—	0	—	0	—	0	—	0	—	0	—	0	—	0	—	0	—	1
	35	0	—	0	—	4	R	0	—	0	—	0	—	0	—	0	—	0	—	0	—	0	—	0	—	0	—	2	P	2
	36	0	—	0	—	4	R	0	—	0	—	0	—	0	—	0	—	0	—	0	—	0	—	0	—	0	—	0	—	1
	37	0	—	0	—	5	R	0	—	0	—	0	—	0	—	0	—	0	—	0	—	0	—	0	—	0	—	0	—	1
	38	0	—	0	—	5	R	0	—	0	—	0	—	0	—	0	—	0	—	0	—	0	—	0	—	0	—	0	—	1
	39	0	—	0	—	3	R	0	—	0	—	0	—	0	—	0	—	0	—	0	—	0	—	0	—	0	—	0	—	1
	40	0	—	0	—	3	R	0	—	0	—	0	—	0	—	0	—	0	—	0	—	0	—	0	—	0	—	0	—	1
	41	0	—	0	—	4	R	0	—	0	—	0	—	0	—	0	—	0	—	0	—	0	—	0	—	0	—	0	—	1
		(0)		(0)		(9)		(0)		(0)		(0)		(0)		(0)		(0)		(0)		(0)		(0)		(0)		(2)		
Determinants (2)	42	0	—	0	—	0	—	0	—	0	—	0	—	0	—	0	—	0	—	0	—	0	—	0	—	0	—	0	—	0
	43	0	—	0	—	0	—	0	—	0	—	0	—	0	—	0	—	0	—	0	—	0	—	0	—	0	—	0	—	0
		(0)		(0)		(0)		(0)		(0)		(0)		(0)		(0)		(0)		(0)		(0)		(0)		(0)		(0)		

Notes:

1. Importance (I) ratings are based on responses made on a 6-point scale, where 0 = Not required, 1 = Dispensable, 2 = Somewhat useful, 3 = Generally useful, 4 = Very important, and 5 = Indispensable.

2. Skill acquisition level (L) ratings are based on responses made on a 3-point scale, where P = Prerequisite, R = Reviewed, and T = Taught.

3. Numbers in parentheses are the total number of skills within a topic area that affect performance (i.e., they were rated above "1" in importance).

[a]Instructors did not reach consensus on importance ratings of these skills. Numbers given are average ratings obtained, rounded to the nearest whole number.

Table 2 (Continued)

Topic Area	Skill	AE I	AE L	AVA I	AVA L	AFTA I	AFTA L	CE-G I	CE-G L	CE-P I	CE-P L	DS I	DS L	EM I	EM L	ET I	ET L	EWC I	EWC L	EWP I	EWP L	FTI I	FTI L	FTII I	FTII L	GM I	GM L	ST I	ST L	No. of Courses in Which Skill Affects Performance
Geometry and Trigonometry (8)	44	0	—	0	—	2	R	0	—	0	—	0	—	0	—	0	—	0	—	0	—	0	—	4	T	0	—	0	—	2
	45	0	—	1	—	5	R	3	P	3	T	0	—	4	R	1	—	0	—	1	—	1	—	4	R	0	—	0	—	5
	46	4[a]	R	0	—	1	—	0	—	0	—	0	—	4	P	3	R	5	R	0	—	4	R	4	R	0	—	4	R	7
	47	0	—	0	—	5	R	0	—	0	—	0	—	0	—	1	—	0	—	0	—	4	R	4	R	0	—	2[a]	P	4
	48	0	—	0	—	2	R	0	—	0	—	0	—	0	—	0	—	0	—	0	—	0	—	0	—	0	—	0	—	1
	49	0	—	0	—	0	—	0	—	0	—	0	—	0	—	0	—	0	—	0	—	0	—	0	—	0	—	0	—	0
	50	0	—	0	—	4	T	0	—	0	—	0	—	0	—	0	—	0	—	0	—	0	—	0	—	0	—	0	—	1
	51	0	—	0	—	0	—	0	—	0	—	0	—	0	—	0	—	0	—	0	—	1	—	0	—	0	—	0	—	0
		(1)		(0)		(5)		(1)		(1)		(0)		(2)		(1)		(1)		(0)		(2)		(4)		(0)		(2)		
Phasors (7)	52	0	—	0	—	5	T	0	—	0	—	0	—	0	—	0	—	0	—	0	—	4	T	0	—	0	—	2	P	3
	53	0	—	0	—	2	T	0	—	0	—	0	—	0	—	0	—	0	—	0	—	0	—	0	—	0	—	0	—	1
	54	0	—	0	—	5	T	0	—	0	—	0	—	0	—	0	—	0	—	0	—	4	R	0	—	0	—	0	—	2
	55	0	—	0	—	5	T	0	—	0	—	0	—	0	—	0	—	0	—	0	—	4	R	0	—	0	—	0	—	2
	56	0	—	0	—	5	T	0	—	0	—	0	—	0	—	0	—	0	—	0	—	0	—	0	—	0	—	0	—	1
	57	0	—	0	—	5	T	0	—	0	—	0	—	0	—	0	—	0	—	0	—	0	—	0	—	0	—	0	—	1
	58	0	—	0	—	0	—	0	—	0	—	0	—	0	—	0	—	0	—	0	—	0	—	0	—	0	—	0	—	0
		(0)		(0)		(6)		(0)		(0)		(0)		(0)		(0)		(0)		(0)		(3)		(0)		(0)		(1)		
Number Bases (4)	59	1	—	5	T	5	T	0	—	0	—	5	T	0	—	3	T	5	T	0	—	0	—	5	T	0	—	4	T	7
	60	0	—	5	T	5	T	0	—	0	—	5	T	0	—	3	T	5	T	0	—	0	—	5	T	0	—	4	T	7
	61	0	—	5	T	5	T	0	—	0	—	5	T	0	—	3	T	2	T	0	—	0	—	5	T	0	—	4	T	7
	62	0	—	5	T	5	T	0	—	0	—	5	T	0	—	1	—	5	T	0	—	0	—	5	T	0	—	4	T	6
		(0)		(4)		(4)		(0)		(0)		(4)		(0)		(3)		(4)		(0)		(0)		(4)		(0)		(4)		
Boolean Algebra (8)	63	0	—	5	T	4	R	0	—	0	—	5	T	0	—	3	T	4	T	0	—	0	—	5	T	4	T	4	T	8
	64	0	—	5	T	5	R	0	—	0	—	5	T	5	T	3	T	5	T	0	—	0	—	5	T	4	T	4	T	9
	65	0	—	5	T	4	R	0	—	0	—	5	T	0	—	2	T	4	T	0	—	0	—	5	T	4	T	4	T	8
	66	0	—	1	—	4	R	0	—	0	—	5	T	0	—	0	—	1	—	0	—	0	—	1	—	0	—	4	T	3
	67	0	—	5	T	4	R	0	—	0	—	5	T	0	—	3	T	3	T	0	—	0	—	5	T	4	T	4	T	8
	68	0	—	0	—	1	—	0	—	0	—	5	T	0	—	0	—	0	—	0	—	0	—	1	—	0	—	4	T	2
	69	0	—	5	T	4	R	0	—	0	—	5	T	0	—	3	T	3	T	0	—	0	—	5	T	0	—	4	T	7
	70	0	—	5	T	4	R	0	—	0	—	5	T	0	—	2	T	3	T	0	—	0	—	5	T	0	—	4	T	7
		(0)		(6)		(7)		(0)		(0)		(8)		(1)		(6)		(6)		(0)		(0)		(6)		(4)		(8)		
Total		(15)		(26)		(59)		(14)		(14)		(23)		(20)		(29)		(34)		(22)		(18)		(28)		(18)		(41)		

Notes:

1. Importance (I) ratings are based on responses made on a 6-point scale, where 0 = Not required, 1 = Dispensable, 2 = Somewhat useful, 3 = Generally useful, 4 = Very important, and 5 = Indispensable.

2. Skill acquisition level (L) ratings are based on responses made on a 3-point scale, where P = Prerequisite, R = Reviewed, and T = Taught.

3. Numbers in parentheses are the total number of skills within a topic area that affected performance (i.e., they were rated above "1" in importance).

[a]Instructors did not reach consensus on importance ratings of these skills. Numbers given are average ratings obtained, rounded to the nearest whole number.

The two nondigital electronics courses--EWP and FTI--have fewer skills in common than do the electrician courses. Both courses require skills in the Arithmetic Operations with Numbers, Units and Conversions, Scientific Notation, and Equations areas. However, EWP, but not FTI, requires skills in Fractions, Decibels, and Logarithms; and FTI, but not EWP, skills in Geometry and Trigonometry and in Phasors. In both courses, required math skills appear to be critical to successful performance. Seventeen of the 22 skills required in the EWP course were rated as either very important or indispensable, as were 16 of the 18 skills required in the FTI course. Two of the skills required at FTI deal with adding and subtracting Phasors (54 and 55); these skills are not required by any of the other courses.

FTII, the advanced FT course, differs from FTI in that it requires fewer skills in Arithmetic Operations with Numbers, no skills in Phasors, more skills in Fractions and in Geometry and Trigometry, and 10 of the 12 Number Bases/Boolean Algebra skills. Thirteen of the 28 skills required in FTII are rated as indispensable; and the other 15, as very important.

The other six basic core courses--AVA, DS, ET, EWC, GM, and ST--deal with both nondigital and digital mathematics concepts. ET, EWC, and ST require more nondigital skills (20, 24, and 29, respectively) than do AVA, DS, and GM (16, 11, and 14, respectively). However, such skills appear to be more important in AVA and EWC than they are in the other courses; 12 of the 16 required nondigital skills at AVA are rated as indispensable, as are 14 of the 24 required skills at EWC. This compares to 6 of the 11 required skills at DS, 5 of the 20 required skills at ET, 2 of the 14 required skills at GM, and none of the 29 required skills at ST.

AVA and DS require 10 and 12 digital skills, respectively, all of which were rated as indispensable. ET, EWC, GM, and ST require 9, 10, 4, and 12 digital skills, respectively. However, of these, only 4 of the 10 skills required at EWC were rated as indispensable.

Since the AVA course consists of self-paced, mastery-learning instruction, it is not surprising that 22 of the 26 required skills were rated as indispensable. Students do not proceed in the course until they evidence mastery; they cannot pass the course until they can perform all math skills required by any test.

The math skills requirements of the AFTA course, the advanced AVA course, are higher than those of any other course included in the study. Forty-eight of the 70 skills were rated as affecting performance at AFTA, and 32 of these skills were rated as indispensable. Thus, if a student is deficient in any one of these 32 skills, he will have difficulty in passing the course. Also, AFTA requires 12 skills that are not required by any of the other courses--7 in Algebraic Expressions, 2 in Geometry and Trigonometry, and 3 in Phasors.

As indicated previously, for all skills rated as affecting performance (i.e., rated above 1 in importance), instructors were asked to indicate whether they were (1) prerequisites and not taught in the course (P), (2) prerequisites but reviewed for students who are deficient (R), or (3) taught as part of the regular curriculum (T). For curriculum design and development, it is necessary to know if required skills are taught in the training pipeline or are learned prior to entering the Navy.

Table 2 shows that all of the basic core courses provide a large amount of review (R) or formal teaching (T). There are 18 skills that are always taught as part of the

curriculum; thus, they apparently are not covered in any of the BE/E schools. These skills are number 15 in Units and Conversions, which deals with conversion between metric and nonmetric systems; 22 in Decibels; 23, 24, and 25 in Logarithms; 31 in Equations; and all 12 of the Number Bases/Boolean Algebra Skills. The diversity of instruction provided in the core courses extends beyond differences in BE/E module prerequisites; it reflects the instructors' perceptions concerning skills that students should have acquired in high school and/or in a basic electronics course, as well as the different proficiency levels that instructors expect of the students entering the course.

A comparison of the skill levels of preceding and advanced courses shows that skills considered prerequisites in the advanced course are not always required in the preceeding course. Number Bases skills are taught in both the AVA and AFTA courses; skill 17 in Units and Conversions is reviewed only in the AVA course but taught in the AFTA course. It appears that skills in sequenced courses should be more closely coordinated to ensure consistency among prerequisite, reviewed, and taught requirements.

Units

Table 3, which lists the units named by instructors in each course surveyed, shows that units 1-4, which are standard electronics units, are used in all courses. It is interesting to note that only four courses--AFTA, EWC, EWP, and ST--use the meter (no. 23). All others use standard United States units of measure, except for DS, which does not use any length measures. Thus, the metric system does not yet dominate Navy electronic systems. Although several courses use the "second" as the smallest unit of time, AE, AVA, AFTA, ET, EWC, and EWP use smaller units of time with metric prefixes. GM was the only one to mention liquid measures (gallon).

Number Bases

The seven schools requiring skills in Number Bases--AVA, AFTA, DS, ET, EWC, FTII, and ST--reported using three principal types: binary, octal, or hexadecimal. ET uses only binary; and the other six, all three types.

Performance Aids

Performance aids may be used during the course or during the exams to minimize mathematical requirements. Computers (including programmable calculators), calculators (nonprogrammable), and slide rules reduce calculation labor and the need to use certain mathematical skills, such as those relating to fractions. For example, if a student wants to add fractions, he can convert each fraction to a decimal number on his calculator and then add the numbers instead of having to find common denominators. Similarly, to simplify the task of adding numbers in Scientific Notation, he can compute the decimal form of each number.

Table 4 lists the performance aids permitted during the course and/or during the exam. As shown, all courses except DS allow some type of performance aid in both course work and exams, with the greatest use of such aids being made in the AFTA, CE-G, EWC, and EWP courses. It is interesting to note that CE-G and CE-P do not permit the same performance aids.

Although computers are permitted in many courses, students generally do not own or have access to them. Slide rules are permitted in class in all courses except DS, and

Table 3

Units Used Most Frequently in Electronics Courses

	Unit	Course														No. Courses in Which Used
		AE	AVA	AFTA	CE-G	CE-P	DS	EM	ET	EWC	EWP	FTI	FTII	GM	ST	
1.	Volt	X	X	X	X	X	X	X	X	X	X	X	X	X	X	14
2.	Ohm	X	X	X	X	X	X	X	X	X	X	X	X	X	X	14
3.	Amp	X	X	X	X	X	X	X	X	X	X	X	X	X	X	14
4.	Watt	X	X	X	X	X	X	X	X	X	X	X	X	X	X	14
5.	Farad	--	X	X	--	--	--	X	--	X	X	X	X	--	X	8
6.	Faraday	--	--	--	--	--	--	--	--	X	X	--	--	--	--	2
7.	Henry	--	--	--	--	--	--	X	--	X	X	X	X	--	X	6
8.	Hertz	X	X	X	--	--	X	X	--	X	X	X	X	--	X	10
9.	Coulomb	--	--	X	--	--	--	--	--	X	X	--	--	--	--	3
10.	Var	--	--	--	--	--	--	--	--	--	--	--	--	--	X	1
11.	Microbar	--	--	--	--	--	--	--	--	--	--	--	--	--	X	1
12.	Micropascal	--	--	--	--	--	--	--	--	--	--	--	--	--	X	1
13.	Hour	X	X	--	X	X	--	--	--	--	--	X	X	--	--	6
14.	Minute	X	X	--	X	X	--	--	X	--	--	X	X	X	--	8
15.	Second	X	X	--	X	X	X	--	X	X	X	X	X	X	X	12
16.	Millisecond	X	X	--	--	--	--	--	X	X	X	--	--	--	--	5
17.	Microsecond	X	X	X	--	--	--	--	--	X	X	--	--	--	--	5
18.	Picosecond	--	--	X	--	--	--	--	--	X	X	--	--	--	--	3
19.	Mile	--	X	X	--	X	--	--	X	X	X	X	X	--	--	8
20.	Yard	--	X	X	--	--	--	--	X	X	X	X	X	--	--	7
21.	Foot	X	X	--	X	X	--	X	X	X	X	X	X	X	--	11
22.	Inch	--	--	--	X	X	--	X	X	X	X	--	--	X	--	7
23.	Meter	--	--	X	--	--	--	--	--	X	X	--	--	--	X	4
24.	Ton	--	--	--	X	--	--	--	--	--	--	--	--	--	--	1
25.	Pound	X	--	--	--	--	--	X	--	--	--	--	--	X	--	3
26.	Degree	--	--	--	--	X	X	X	--	--	--	X	X	X	X	7
27.	Radian	--	--	--	--	--	--	--	--	--	--	--	--	--	X	1
28.	Cycle	--	--	--	--	--	--	--	--	--	--	--	--	--	X	1
29.	Revolution	--	--	--	--	--	--	X	--	--	--	X	X	X	X	5
30.	Minute of an Arc	--	--	--	--	--	--	--	--	--	--	X	X	--	--	2
31.	Knot	--	--	--	--	--	--	--	--	--	--	X	X	--	--	2
32.	Mhos	--	--	--	--	--	--	--	--	X	X	--	--	--	--	2
33.	Horsepower	--	--	--	--	X	--	--	--	--	--	--	--	--	--	1
34.	Mill	--	--	--	--	X	--	--	--	--	--	--	--	X	--	2
35.	Circular Mill	--	--	--	--	X	--	X	--	--	--	--	--	--	--	2
36.	Gallon	--	--	--	--	--	--	--	--	--	--	--	--	X	--	1
37.	Standard US Measurements	--	--	--	X	--	--	--	--	--	--	--	--	--	--	1
38.	American Wiregate Sizes	--	--	--	--	X	--	--	--	--	--	--	--	--	--	1
39.	Standard Magnetism Units	--	--	X	--	--	--	--	--	--	--	--	--	--	--	1
40.	Watts/sq ft	--	--	--	--	X	--	--	--	--	--	--	--	--	--	1
41.	Dynes/cm^2	--	--	--	--	--	--	--	--	--	--	--	--	--	X	1
42.	Hertz/sec	--	--	--	--	--	--	--	--	X	X	--	--	--	--	2
43.	Rpm	--	--	--	--	--	--	X	--	--	--	--	--	X	--	2
44.	Gal/min	--	--	--	--	--	--	--	--	--	--	--	--	X	--	1
45.	Gal/hr	--	--	--	--	--	--	--	--	--	--	--	--	X	--	1
46.	Cuft/sec	--	--	--	--	--	--	--	--	--	--	--	--	X	--	1
47.	Ft/sec	--	--	--	--	--	--	--	--	--	--	--	--	X	--	1
48.	Cm/sec	--	--	--	--	--	--	--	X	--	--	--	--	--	--	1
49.	Lb/sq in	--	--	--	--	X	--	X	--	--	--	--	--	X	--	3
50.	Ft/lb	--	--	--	--	--	--	X	--	--	--	--	--	--	--	1
51.	Lb/ft	--	--	--	--	--	--	X	--	--	--	--	--	--	--	1
	Total	12	14	13	11	17	7	17	12	20	20	17	17	19	17	213

Table 4

Performance Aids Permitted in Electronics Courses

Performance Aid	Course														No. Courses in Which Used
	AE	AVA	AFTA	CE-G	CE-P	DS	EM	ET	EWC	EWP	FTI	FTII	GM	ST	
In Course															
Computer	–	X	X	X	X	–	–	–	X	X	–	–	–	X	7
Calculator	X	X	X	X	X	–	X	X	X	X	X	X	X[a]	X	13
Slide Rule	X	X	X	X	X	–	X	X	X	X	X	X	X	X	13
Log Tables	X	X	X	X	–	–	X	X	X	X	X	X	–	X	11
Trig Tables	X	X	X	X	–	–	X	X	X	X	X	X	–	X	11
Formula Sheets	X	X	X	X	X	–	X	X	X	X	X	X	–	X	12
No aids used	5	6	6	6	4	0	5	5	6	6	5	5	2	6	67
In Exam															
Computer	–	–	–	X	–	–	–	–	X	X	–	–	–	–	3
Calculator	X	X	X	X	–	–	X	X	X	X	X	X	X[a]	–	11
Slide Rule	X	X	X	X	X	–	X	X	X	X	X	X	X	–	12
Log Tables	X	–	X	X	–	–	–	X	X	X	X	X	–	X	9
Trig Tables	X	–	X	X	–	–	–	X	X	X	X	X	–	X	9
Formula Sheets	X	–	X[c]	–	–	–	–	–	X[b]	X[b]	–	–	–	X	5
No aids used	5	2	5	5	1	0	2	4	6	6	4	4	2	3	49

[a] Some instructors permit use of calculators, but not all.

[b] Only formula sheets given by instructors.

[c] Formula sheets not permitted on Phase 3 exam.

during exams in all but DS and ST. Although all students must own a slide rule, few, if any, know how or care to use them. The low cost of simple calculators has made them the most universally used performance aid for arithmetic calculations. All courses except DS permit their use in class, and all but CE-P, DS, and ST permit them during exams. Thus, in most courses, students are not required to perform many mathematical operations manually.

All courses but CEP, DS, and GM permit logarithm and trigonometry tables to be used in class; and all but AVA, CE-P, DS, EM, and GS, during exams. Formula sheets are provided for use in class at 12 of the 14 schools; however, since they were not examined, it is not known whether they actually reduce the required mathematical skills. On some formula sheets, various forms of equations are given, eliminating the need for students to transpose them (e.g., P = IE; I = P/E; E = P/I). On others, however, equations may be presented in only one form.

Follow-up Survey

Importance and skill acquisition ratings assigned to mathematical skills by EM, ET, FTI, and GM instructors in the follow-up survey were consistent with those assigned in the original survey. As shown in Table 5, the total time spent reviewing math topics surveyed ranges from 2.75 hours (EM) to 12.75 hours (ET); and the total time spent teaching all math topics surveyed, from 0.50 hours (EM) to 16.75 hours (GM). Thus, it appears that students are expected to enter the school with an array of mathematical skills.

Table 5

Mean Time Spent Reviewing (R) and Teaching (T) Math Topics Surveyed

	EM (45 Hours) (9 Weeks)		FTI (55 Hours) (11 Weeks)		GM (60 Hours) (12 Weeks)		ET (85 Hours) (17 Weeks)	
	R	T	R	T	R	T	R	T
Mean Time (Hours)	2.75	0.50	5.50	0.25	3.50	16.75	12.75	13.75
Percent of Total Training Time	0.06	0.011	0.100	0.004	0.058	0.279	0.147	0.162

CONCLUSIONS

1. Although a number of mathematical skills are considered to be course prerequisites, many "A" School students require instruction in these skills in the form of review or reteaching before they can perform successfully.

2. In most courses, students are not required to perform mathematics operations manually.

3. The amount of time spent on review and teaching of mathematics is minimal.

RECOMMENDATIONS

1. Further studies should be conducted to:

a. Determine if "A" school mathematics requirements are justified; that is, if they are necessary for job performance or as an enabling skill for another skill critical to job performance.

b. Determine if entry levels of electronics Class "A" school students match prerequisite requirements.

c. Determine the extent to which BE/E preparatory schools provide training in mathematical skills considered as prerequisite to the electronics Class "A" schools.

2. Given the variability of mathematical skills required in the Navy's electricity/electronics courses, curriculum developers should ensure that curricula are designed to provide instruction only in those skills required by an individual course.

REFERENCES

Anderson, A. V. Training, utilization, and proficiency of Navy electronics technicians: IV: Proficiency in mathematics (PRASD Report No. 190). San Diego: U.S. Naval Personnel Research Activity, October 1962.

Cooke, N. M., & Adams, H. E. R. Basic mathematics for electronics. New York: McGraw Hill, 1970.

Cox, J. A., & Montgomery, R. C. A study of mathematical skills requirements for basic electronics in the U.S. Army Defense School (ADHRU/Consulting Report). Fort Bliss, TX: U.S. Army Air Defense Human Research Unit, October 1964.

Johnson, K. A. Retention of electronic fundamentals: Differences among topics (Tech. Bulletin STB 70-1). San Diego: U.S. Naval Personnel Research Activity, August 1969.

Stauffer, A. J. Development of a test to determine the training needs of sonar maintenance (PRFASD Report No. 69). San Diego: U.S. Naval Personnel Research Field Activity, March 1955.

Steinemann, J. H. An advanced survey of electronics training in military and civilian organizations (Tech. Bulletin 65-11). San Diego: U.S. Naval Personnel Research Activity, March 1965.

APPENDIX

MATHEMATICAL SKILLS SURVEY

NPRDC MATH SKILLS SURVEY

CONTENTS

	Page		Page
Arithmetic Operations with Numbers (1-4)	1	Algebraic Expressions (33-41)	4
Estimation (5)	1	Determinants (42-43)	4
Fractions (6-10)	1	Geometry and Trigonometry (44-51)	5
Units and Conversions (11-17)	2	Phasors (52-58)	6
Scientific Notation (18-21)	2	Number Bases (59-62)	6
Decibels (22)	3	Boolean Algebra (63-70)	7
Logarithms (23-26)	3	Computational Aids	8
Equations (27-32)	3		

SCALE

5	Indispensable	The student will not be able to pass your portion of the course if he lacks this skill.
4	Very Important	The student's performance will be affected substantially if he lacks this skill, but it will not cause him to fail your portion of the course.
3	Generally Useful	The student's performance will be affected if he lacks this skill.
2	Somewhat Useful	The student's performance will be slightly affected if he lacks this skill, i.e., there is at least one instance where the student is asked to demonstrate or use this skill.
1	Dispensable	The student's performance will not be affected if he lacks this skill but it appears during your portion of the course, i.e., the skill may be referred to when answering a question or for enrichment when time permits (a "nice to know" skill).
0	Not Required	The skill does not appear during your portion of the course.

SKILL ACQUISITION

P	Prerequisite	Must possess skill on entrance to course.
R	Reviewed	Some level of skill is assumed, but skill is reviewed in course.
T	Taught	No previous knowledge assumed; taught explicitly as a skill for the course.

ARITHMETIC OPERATIONS WITH NUMBERS

1. Addition, subtraction, multiplication, and division of numbers. (Circle One)

   1. $22 - 375 =$ ____
   2. $-22.8 \overline{)378.4} =$ ____

   5 / 4 P / 3 R / 2 T / 1 / Not Required

2. Squares and square roots of positive numbers.

   1. $3^2 =$ ____
   2. $\sqrt{57.5} =$ ____

   5 / 4 P / 3 R / 2 T / 1 / Not Required

3. Powers and roots of positive numbers greater than squares and square roots.

   1. $4^5 =$ ____
   2. $\sqrt[3]{18} =$ ____

   5 / 4 P / 3 R / 2 T / 1 / Not Required

4. Percentages of numbers.

   1. 105 of 60 = ____
   2. 21 is what % of 78? ____

   5 / 4 P / 3 R / 2 T / 1 / Not Required

ESTIMATION

5. Estimation of answers to arithmetic computation. (Circle One)

   Estimate the answer to the following operations:

   1. $\frac{(869)(98007)}{654} =$ ____
   2. $\frac{(987654)(100077)}{(7989)(87654)} =$ ____

   5 / 4 P / 3 R / 2 T / 1 / Not Required

FRACTIONS

6. Addition and subtraction of fractions.

   1. $\frac{1}{4} + \frac{2}{4} =$ ____
   2. $2\frac{3}{5} - \frac{2}{3} =$ ____

   5 / 4 P / 3 R / 2 T / 1 / Not Required

7. Multiplication and division of fractions.

   1. $\frac{1}{5} \times \frac{2}{3} =$ ____
   2. $9\frac{1}{5} \div 4\frac{2}{5} =$ ____

   5 / 4 P / 3 R / 2 T / 1 / Not Required

8. Powers and roots of fractions.

   1. $\left(\frac{2}{3}\right)^3 =$ ____
   2. $\sqrt{\frac{9}{5}} =$ ____

   5 / 4 P / 3 R / 2 T / 1 / Not Required

9. Reduction of numeral fractions to lowest terms. (Circle One)

   Reduce the following fractions:

   1. $\frac{36}{48} =$ ____
   2. $\frac{18}{7} =$ ____

   5 / 4 P / 3 R / 2 T / 1 / Not Required

10. Simplification of complex fractions.

    Simplify the following fractions:

    1. $\frac{2}{\frac{1}{2}} =$ ____
    2. $\frac{2+\frac{1}{3}}{\frac{1}{3}-3} =$ ____

    5 / 4 P / 3 R / 2 T / 1 / Not Required

UNITS AND CONVERSIONS

11. Addition and subtraction of like units.
    1. [illegible] milliseconds = 200 milliseconds = _____
    2. 95 millivolts + 0.10 volts = _____

12. Multiplication and division of like units.
    1. 20 seconds × 5 seconds = _____
    2. 35 millivolts ÷ 100 microvolts = _____

13. Multiplication and division of unlike units.
    1. 20 kilowatts × 20 minutes = _____
    2. $\frac{10\ cm}{2\ milliseconds}$ = _____

14. Squares and square roots of units.
    1. $(30\ seconds)^2$ = _____
    2. $\sqrt{250\ watts}$ = _____

15. Unit conversion between non-metric and metric systems.
    1. 254 mm = _____ inches
    2. 320 oz = _____ grams

16. Unit conversion within a metric system.
    1. 5 kilovolts = _____ volts
    2. 500 seconds = _____ milliseconds

17. Unit conversion within a non-metric system.
    1. 1000 yards = _____ feet
    2. 9869 minutes = _____ hours

WHAT UNITS ARE USED?

SCIENTIFIC NOTATION

18. Representation of numbers in scientific notation.

    Express the following numbers in scientific notation:
    1. 96,000,000 = _____
    2. 0.0000000097 = _____

19. Addition and subtraction of numbers in scientific notation.
    1. $6 \times 10^6 + 4 \times 10^5$ = _____
    2. $9.5 \times 10^{-4} - 5 \times 10^{-5}$ = _____

20. Multiplication and division of numbers in scientific notation.
    1. $(2.5 \times 10^5) \times (8 \times 10^{-7})$ = _____
    2. $(4.8 \times 10^7) \div (2 \times 10^5)$ = _____

21. Powers and roots of numbers in scientific notation.
    1. $(3 \times 10^4)^3$ = _____
    2. $\sqrt[3]{8 \times 10^{-13}}$ = _____

(Circle One)

5 4 P 3 R 2 T 1 Not Required

A-3

DECIBELS

22. Decibels. (Circle One)

5

4 P

3 R

2 T

1

Not Required

1. A power gain of 28 decibels (dB) increases the initial power by what factor?

2. A voltage ratio of 4000 is _____ dB.

LOGARITHMS

23. Logs and antilogs found from log tables.

1. $\log_{10} 287.604 =$ _____

2. antilog $3.6863 =$ _____

24. Arithmetic computation using logs.

Compute using logs:

1. $(2587)(547) =$ _____

2. $\frac{\sqrt{(598)}\,(876)}{554} =$ _____

25. Solutions of logarithmic and exponential equations.

Solve for x:

1. $\log \frac{x}{100} = 3.9345$

2. $6^x = 528$

26. Logs of numbers to bases other than 10 using log base 10 log tables.

Compute the following logarithms using base 10 log tables:

(e = 2.71828)

1. $\log_e 1247 =$ _____

2. $\log_5 258 =$ _____

EQUATIONS

27. Substitution of known values into a given formula.

1. Given $C = \frac{1}{X} + \frac{1}{B}$ and A = 12, B = 19. Find C.

2. Given $Z = xy$ and x = 100, y = 50. Find Z.

28. Transpositions of algebraic expressions.

1. Solve for x:

$\frac{1}{x} + \frac{1}{2} = 8$

2. Solve for y:

$y^2 - 5 = 11$

29. Application of transpositions on equations with more than one variable.

1. Solve for x:

$z = 24x$

2. Solve for y:

$x = \frac{y^2}{c^2} + 2y^2 + 9$

33. Solutions of quadratic equations.

Solve for x:

1. $x^2 + x - 6 = 0$

2. $3x^2 - 2x - 4 = 0$

31. Solutions of second order simultaneous equations.

1. Solve for a_1 and a_2:

$3a_1 + 4a_2 = 6$

$2a_1 - a_2 = 14$

2. Solve for b_1 and b_2:

$\frac{2}{b_1} + \frac{3}{b_2} = 8$

$\frac{3}{2b_1} - \frac{2}{b_2} = 7$

32. Solutions of third order simultaneous equations.

Given: $2a+4b+2c = 14$
$4a+2b+4c = 4$
$2a+6b+8c = 28$

1. Solve for a.

2. Solve for b.

A-4

ALGEBRAIC EXPRESSIONS

33. Addition and subtraction of algebraic expressions. (Circle One)

1. $2a + 3a =$ ____
2. $(7x^2-3y^3) - (9x^2+5y^3+3z) =$ ____

5 4 P 3 R 2 T 1 Not Required

34. Multiplication and division of simple algebraic expressions (laws of exponents).

1. $3a^2 \times 5a^{-3} =$ ____
2. $\frac{a^{-3} \times a^3b^4}{a^{-6}b^3} =$ ____

5 4 P 3 R 2 T 1 Not Required

35. Multiplication of algebraic expressions up to binomials.

1. $a(4a+3) =$ ____
2. $(x+4)(3x-4) =$ ____

5 4 P 3 R 2 T 1 Not Required

36. Multiplication of algebraic expressions larger than binomials.

1. $(x+4)(3x+5b-4) =$ ____
2. $(5a+3b+2c)(7a-5b+3c) =$ ____

5 4 P 3 R 2 T 1 Not Required

37. Division of algebraic expressions.

1. $(4a^2-a) \div a =$ ____
2. $(a^3-4a+2a^2-8) \div (x+2) =$ ____

5 4 P 3 R 2 T 1 Not Required

38. Powers and roots of simple algebraic expressions (laws of exponents). (Circle One)

1. $\left(\frac{a^2}{b^3}\right)^2 =$ ____
2. The cubic root of a^3b^9 is ____

5 4 P 3 R 2 T 1 Not Required

39. Powers and roots of polynomials.

1. $(a+3)^3 =$ ____
2. $\sqrt{4a^4+12a^3+25a^2+24a+16} =$ ____

5 4 P 3 R 2 T 1 Not Required

40. Addition and subtraction of fractional algebraic expressions.

1. $\frac{5a}{cd} - \frac{2a}{cd} =$ ____
2. $\frac{3}{a} + \frac{7}{ab} =$ ____

5 4 P 3 R 2 T 1 Not Required

41. Factoring algebraic expressions.

Factor the following polynomials:

1. a^2-b^2
2. $14a^2+11a-15$

5 4 P 3 R 2 T 1 Not Required

DETERMINANTS

42. Evaluation of determinants. (Circle One)

Evaluate the following determinants:

1. $\begin{vmatrix} 1 & 2 \\ 4 & 6 \end{vmatrix}$
2. $\begin{vmatrix} -1 & 2 & 4 \\ -7 & 8 & -6 \\ 7 & 4 & 2 \end{vmatrix}$

5 4 P 3 R 2 T 1 Not Required

43. Solutions of simultaneous equations using determinants.

Express solutions to the following simultaneous equations as determinants:

1. $2x+y = 6$
   $3x-y = 5$
2. $2a+4b+2c = 14$
   $4a+2b+4c = 4$
   $2a+6b+c = 28$

5 4 P 3 R 2 T 1 Not Required

A-5

GEOMETRY AND TRIGONOMETRY

44. Conversion of radian and degree measures of angles.

1. Convert 135° to radians.
2. Convert 1.5 radians to degrees.

(Circle One)

5
4 P
3 R
2 T
1
Not Required

45. Pythagorean theorem.

Solve for the length of the missing side of the following right triangles:

1.

2.

5
4 P
3 R
2 T
1
Not Required

46. Use of trigonometric tables to find the specified function of a given angle, or the angle of a given function.

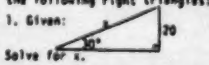
1. cos 30.4° = ____
2. sin θ = .2750, θ = ____

5
4 P
3 R
2 T
1
Not Required

47. Solutions to right triangles.

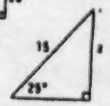
Solve for the missing components of the following right triangles:

1. Given:



Solve for x.

2. Given:



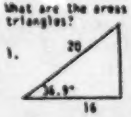
Solve for x.

(Circle One)

5
4 P
3 R
2 T
1
Not Required

48. Calculations of the area of a given triangle.

What are the areas of the following triangles?

1. 

2.

5
4
3
2
1

49. Solutions for unknown parts of a non-right triangle using law of sines and law of cosines.

1. Given:

Solve for A.

2. Given:

Solve for A.

5
4 P
3 R
2 T
1
Not Required

50. Solutions of amplitude, frequency, phase angle, period and angular velocity of a given periodic function.

1. What is the frequency, amplitude and phase angle of the following periodic function?

$y = 27 \cos(367t + 80°)$

2. What is the period and angular velocity of the following periodic function?

$y = 18 \sin(874t + 20°)$

(Circle One)

5
4 P
3 R
2 T
1
Not Required

51. Application of sum and difference identities.

1. Given: $\sin a = 0.5592$
$\cos a = 0.8290$
$\sin b = 0.9613$
$\cos b = 0.2756$

What is $\cos (a+b)$?

2. Given: $\sin a = 0.7660$
$\cos a = 0.6428$
$\sin b = 0.8660$
$\cos b = 0.5000$

What is $\sin (a-b)$?

5
4 P
3 R
2 T
1
Not Required

A-6

PHASORS

52. Conversion of polar and rectangular coordinates. (Circle One)

1. Convert $25\angle 30°$ to rectangular coordinates.
2. Convert $12+j23.3$ to polar coordinates.

5 4 P 3 R 2 T 1 Not Required

53. Powers and roots of signed numbers.

1. $(-3)^3 =$ ____
2. $\sqrt{-9} =$ ____

5 4 P 3 R 2 T 1 Not Required

54. Addition and subtraction of phasors in rectangular form.

1. $(6+j2) + (7+j9) =$ ___
2. $(6+j3) - (8-j6) =$ ___

5 4 P 3 R 2 T 1 Not Required

55. Addition and subtraction of polar phasors.

1. $20\angle 24° + 5\angle 10° =$ ____
2. $7\angle 90° - 9\angle 56° =$ ____

5 4 P 3 R 2 T 1 Not Required

56. Multiplication and division of phasors in rectangular form.

1. $(3+j4) \times (8+j3) =$ ____
2. $(2+j2) \div (2+j3) =$ ____

5 4 P 3 R 2 T 1 Not Required

57. Multiplication and division of polar phasors. (Circle One)

1. $25\angle 24° \times 5\angle 26° =$ ____
2. $8\angle 36° \div 2\angle 21° =$ ____

5 4 P 3 R 2 T 1 Not Required

58. Powers and roots of polar phasors.

1. Find the square of $12\angle 25°$.
2. Find the square root of $49\angle 30°$.

5 4 P 3 R 2 T 1 Not Required

NUMBER BASES

59. Conversion of numbers to different number systems.

1. Convert 2357 from an octal to a decimal number.
2. Convert 64 from an octal number to a binary number.

5 4 P 3 R 2 T 1 Not Required

What number systems are used?

- ☐ Binary
- ☐ Octal
- ☐ Hexadecimal

60. Addition and subtraction in number systems from #59. (Circle One)

1. Add the following binary numbers.

   1101011
   + 1010101

2. Subtract the following octal numbers.

   476
   - 357

5 4 P 3 R 2 T 1 Not Required

61. Multiplication and division in number systems from #59.

1. Multiply the following binary numbers.

   101001
   x 110101

2. Divide the following octal numbers.

   $763\overline{)5431}$

5 4 P 3 R 2 T 1 Not Required

62. Complements of binary numbers.

1. The 1's complement of the binary number 110101 is _____.
2. The 2's complement of the binary number 11101101 is _____.

5 4 P 3 R 2 T 1 Not Required

Extra categories/skills

What computational aids are allowed during your portion of the course/exam?

	During Course	During Exam
Computers	_____	_____
Calculators	_____	_____
Slide Rules	_____	_____
Log tables	_____	_____
Trig. Tables	_____	_____
Formula Sheets	_____	_____
Others	_____	_____
	_____	_____
	_____	_____
	_____	_____

DISTRIBUTION LIST

Assistant Secretary of Defense, Deputy Assistant Secretary (Equal Opportunity)
Deputy Under Secretary of Defense Research and Engineering (Research and Advanced Technology), Military Assistant for Training and Personnel Technology
Assistant Secretary of the Navy (Manpower Reserve Affairs & Logistics), (Principal Assistant for Manpower and Reserve Affairs)
Chief of Naval Operatons (OP-01), (OP-11), (OP-12), (OP-13), (OP-115) (2), (OP-987H)
Chief of Naval Material (NMAT 00), (NMAT 0722)
Chief of Naval Research (Code 450) (3), (Code 452), (Code 458)
Chief of Information (OI-2252)
Chief of Naval Education and Training (02), (N-2), (N-5)
Chief of Naval Technical Training (017)
Director of Navy Laboratories
Commandant of the Marine Corps (MPI-20)
Commander Naval Military Personnel Command (NMPC-013C)
Commander Training Command, U.S. Atlantic Fleet (Code N3A)
Commander Training Command, U.S. Pacific Fleet
Commanding Officer, Fleet Anti-Submarine Warfare Training Center, Pacific
Commanding Officer, Fleet Combat Training Center, Atlantic (Code 02)
Commanding Officer, Fleet Combat Training Center, Pacific (Cod 00E)
Commanding Officer, Fleet Training Center, San Diego
Commanding Officer, National Naval Dental Center
Commanding Officer, Naval Education and Training Program Development Center (Technical Library) (2)
Commanding Officer, Naval Education and Training Support Center, Pacific (Instructional Program Development Dept. Code N1B)
Commanding Officer, Naval Health Sciences Education and Training Command (Code 2) (2)
Commanding Officer, Naval Technical Training Center (Cod 01E)
Commanding Officer, Office of Naval Research Branch Office, Chicago (Coordinator for Psychological Sciences)
Commanding Officer, Shore Intermediate Maintenance Activity
Director, Defense Activity for Non-Traditional Education Support
Director, Naval Education and Training Program Development Center Detachment
Director, Training Analysis and Evaluation Group (TAEG)
Officer in Charge, Central Test Site for Personnel and Training Evaluation Program
Officer in Charge, Naval Education and Training Information Systems Activity Detachment
Superintendent, Naval Postgraduate School
Fleet Master Chief, Naval Material Command (NMAT 00C)
Fleet Master Chief, U.S. Atlantic Fleet (Code 003)
Fleet Master Chief, U.S. Pacific Fleet
Fleet Master Chief, Chief of Naval Education and Training (Code 003)
Commanding Officer, Army Research Institute for the Behavioral and Social Sciences, Alexandria (Reference Service)
Director, U.S. Army TRADOC Systems Analysis Activity, White Sands Missile Range (Library)
Chief, Army Research Institute Field Unit—USAREUR (Library)
Chief, Army Research Institute Field Unit, Fort Harrison
Commander, Air Force Human Resources Laboratory (Scientific and Technical Information Office)
Commander, Air Force Human Resources Laboratory, Lowry Air Force Base (Technical Training Branch)
Commander, Air Force Human Resources Laboratory, Williams Air Force Base (CNET Liaison Office)

Commander, Air Force Human Resources Laboratory, Wright-Patterson Air Force Base (Logistics and Technical Training Division)
Commander, 314 Combat Support Group, Little Rock Air Force Base (Career Progression Section)
Program Manager, Life Sciences Directorate, Bolling Air Force Base
Commanding Officer, U.S. Coast Guard Research and Development Center, Avery Point
Commanding Officer, U.S. Coast Guard Training Center, Alameda
Defense Technical Information Center (DTIC) (12)

BOOLEAN ALGEBRA

63. Conversion of Boolean expressions to truth tables.

1. $A = 1$, $B = 1$. What is the output of $A \cdot \overline{B}$?
2. Construct a truth table for $AB + \overline{CD}$.

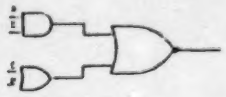
(Circle One)

5
4 P
3 R
2 T
1
Not Required

64. Conversion of logic diagrams to truth tables.

1. $A = 1$, $B = 0$. What is the output at C?

2. Construct a truth table for the following logic diagram:



(Circle One)

5
4 P
3 R
2 T
1
Not Required

65. Conversion of Boolean expressions to logic diagrams.

1. Convert $AB+\overline{CD}$ to a logic diagram.
2. Convert $(A+\overline{B})(\overline{CD})$ to a logic diagram.

(Circle One)

5
4 P
3 R
2 T
1
Not Required

66. Simplification of Boolean expressions.

1. Simplify: $(A+\overline{A}B)A$
2. Simplify: $\overline{A(\overline{A+B})+C\overline{B}}$

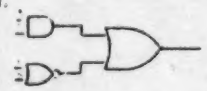
(Circle One)

5
4 P
3 R
2 T
1
Not Required

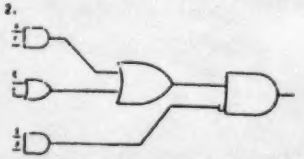
67. Conversion of logic diagrams to Boolean expressions.

Write the Boolean expression for the following logic diagrams:

1.



2.



(Circle One)

5
4 P
3 R
2 T
1
Not Required

68. Simplification of Boolean expressions involving minterms (Veitch diagrams).

1. Simplify $ABC+AB\overline{D}+AC+BD+\overline{A}\overline{D}+\overline{B}CA$
2. Simplify $ABC+ABD+B\overline{B}$

5
4 P
3 R
2 T
1
Not Required

69. Conversion of truth tables to Boolean expressions.

1. Given:

A	B	Output
1	1	1
1	0	1
0	1	0
0	0	0

Construct a Boolean expression for the truth table, which uses A and B as inputs and produces the given output.

2. Given:

A	B	C	Output
1	1	1	1
1	1	0	1
1	0	1	0
1	0	0	0
0	1	1	1
0	1	0	0
0	0	1	0
0	0	0	0

Construct a Boolean expression for the truth table, which uses A, B, and C as inputs and produces the given output.

(Circle One)

5
4 P
3 R
2 T
1
Not Required

70. Conversion of truth tables to logic diagrams.

1. Given:

A	B	Output
1	1	1
1	0	0
0	1	0
0	0	0

Construct a logic diagram for the truth table, which uses A and B as inputs and produces the given output.

2. Given:

A	B	C	Output
1	1	1	1
1	1	0	1
1	0	1	0
1	0	0	0
0	1	1	1
0	1	0	0
0	0	1	1
0	0	0	0

Construct a logic diagram for the truth table, which uses A, B, and C as inputs and produces the given output.

5
4 P
3 R
2 T
1
Not Required

A-8